ILLUSORY CHANGES RESULTING FROM THE PERCEPTION OF A PURE TONE PRESENTED IN SYMPATHY WITH A COMPLEX STIMULUS

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ABSTRACT

An illusion is explored in which a constant tone, tuned to an arpeggio, is perceived to change in pitch in the absence of an actual frequency change. The effects of dichotic and monaural presentation, frequency range of the arpeggio, and loudness of constant tone are explored in the presence of small or zero frequency changes in the constant tone. The role of attentional factors in this illusion is discussed.

CHAPTER I

INTRODUCTION

REVIEW OF THE LITERATURE

Our senses - seeing, hearing, touching, tasting, feeling - are the windows to the world we live in. They provide us with a "picture" of this world. When activated, our sense organs send "signals" i.e. electric impulses by way of the nervous system to our brains. But the "picture" we get is not one of electric impulses so somewhere along the line these impulses must have been processed and transformed. This can be illustrated by our ability to hear meaningful messages rather than the very complicated acoustical waveforms of speech.

Several current texts take the view that the human is a processor of information; "the picture that has emerged from the results of an increasingly large number of experiments in psychology, physiology, neurology and the communication sciences implies that the nervous system performs substantial alterations of the physical image received by the sense organs" (Norman, 1976).

The information processing approach to human perception suggests that we interpret our sensory information and extract its psychological content. And to do this, we need to process the incoming signals and interpret them on the basis of our past experiences. Memory no doubt plays an active role in this process. It provides the information about the past that is necessary for a proper understanding of the present so that we can make decisions and take actions on the information we have received. Our interpretation of sensory signals also depends on the whole environment in which they are imbedded. Thus, ambiguous stimuli get interpreted in completely unambiguous ways, depending on the context surrounding them. All of us must have had the experience of misreading a word or failing to see an indistinct or distant object. Yet, when told what the word or object really was, we looked again and suddenly it was clear and distinct.

Someplace along the line, the capacity of the human to deal with incoming information is also severely limited. It is as if, at some stage of the analysis of incoming information, only a small portion of the incoming signal is selected for further processing. (eg. Broadbent, 1971). This limitation and selection is related to the phenomenon of attention. For instance, when we concentrate fully on a book, noises in the environment fade from consciousness; when our thoughts wander in a lecture, we find ourselves unable to recall the speaker's message, although we were aware that he was speaking.

It is not difficult to see that with any sensory experience there are two kinds of attributes - physical and psychological. In the case of hearing, the subject of interest in this thesis, a physical wave can be accurately specified by its waveform - the description of its energy or pressure variation over time - or by its spectrum - the description of how much energy is present at each frequency. The psychological aspects are not so easily specified. The two most obvious psychological dimensions are loudness and pitch. Other aspects include timbre, dissonance, consonance and musicality. These psychological impressions are dependent upon the past experiences and attentiveness of the observer and the context in which the stimulus occurs. Because of the subjective nature of these psychological impressions it would not be difficult for the observer to "misperceive".

Misconceptions or illusions are not uncommon even though we may not be very aware of them. What are illusions? There are many kinds of illusions. Almost everyone of us would have experienced these misjudgements of the real world. The most common and well established are the visual ones. They have a long historical tradition and their processes have been explored along many dimensions (eg. Robinson, 1972, Coren & Girgus, 1978). Some of the aspects investigated for their effects on illusory situations include the effect of experience or prior learning that one brings to the situation.[1]

The studies of Vernon (1973) show how visual perception is the result of inference and interpretation i.e. we impose meaning on what we see. For instance, representational symbolic shapes have been shown to be distorted in reproduction according to the meaning or the label imposed on the original drawing (eg. Charmichael, Hogan & Walter, 1932).

1. For example, the illusory effects of the Muller-Lyer and Ponzo lines are used to show that the perceived distortions are likely to be the result of cognitive rather than peripheral or physical processes. Gregory (1972) pointed out that Zulus, who have little experience of perspective cues because of the "roundness" of the environment in which they live, are hardly affected by the illusion figures. Vernon (1973) found that artists, although skilled and experienced in the use of perspective cues are only slightly less susceptible to the illusions than the average person.

Similarly, meaningless random polygons are often being interpreted as objects. (eg. Vanderplus & Garvin, 1959). These all demonstrate the perceiver's search for "structure" in the midst of uncertainty - an effect that has been well documented by Garner (1962).

It is an established fact that there are large individual differences in perception (eg. Davidoff, 1975), and that we impose a different structure or meaning on what we perceive according to such factors as our experiences and our cultural background (eg. Whorf, 1956). Cultural factors in colour perception have been explored in some depth (see, for example, the studies reported in Taylor, 1976). Furthermore, it seems likely that similar phenomena are possible in the other sensory modalities including touch (eg. Wong, 1977) and audition (eg. Deutsch, 1969). In the case of music, which itself is greatly influenced by cultural factors, it is especially likely that illusions could arise, simply because musical systems provide a context within which auditory stimuli are perceived and processed.

Because of the musical disposition of the nature of the stimuli used in this study, the writer would like to review some aspects of music and its psychology that may be of relevance.

What is music? In the fields of music theory and musicology, both simple and compound sound are treated as concrete building material having differing valences (eg. Winckel, 1967). In this way, a "function" is ascribed to each building block with respect to the others, whereby a distinctive architecture is formed, possessing a singular tonal character. And music is defined as a multiform complex function of sound series by Winckel (1967). Because each building block, as a sound carrier has a functional value with respect to the other building blocks which are arranged in time before, after and above it, a sound experience, according to Winckel (1967) is not a musical experience. As Adorno (1962) puts it, "each tone that falls into the musical field is immediately more than simply a tone, eventhough there are no qualities discoverable which are more than those simply of tone". This could be illustrated by an example of listening to the sounds of bells. We find much more than simple struck chord relationships. First of all, there is the onset of each individual sound; then there is the interference effect of the sounds acting on each other, bringing in new sound qualities; and finally there is the decay of the sound, a breaking-up of the "glistening colour" into the most simple components. This process occurs with the generation of every musical sound; it leads us to observe that with the intoning of written note values, additional unintended sound components are generated which can even be unharmonic with respect to the original sound components. It has also been shown that absolute purity of intonation is very seldom achieved in practical music, and need not even be striven for in order to give the music an experiential content (eg. Ward, 1970). The slight deviation from the "eternally pure harmony" constitutes the seasoning in the dish. And this "generates atmosphere and awakens associations with earlier experiences, which can arouse for example, religious feelings (bell and gong) and stimulate the imagination and spirit" (Winckel, 1967). Does this mean music has "meaning" and affects emotion?

There is evidence based upon introspective reports and behavioural and physiological studies of performers and audiences, that music does indeed have meaning and arouses emotion. Composers have demonstrated in their writings and by the expression marks used in their musical scores, their faith in the affective power of music. On the physiological level, music is found to have a marked effect on pulse, respiration and external blood pressure, delays the onset of muscular fatigue and has a marked effect upon the psychogalvanic reflex - changes that normally accompany emotional experience (eg. Critchley & Henson, 1977).

Because the listener inevitably brings to the act of perception, his past experiences, it seems more reasonable to suppose that physiological changes observed are a response to the listener's mental attitude rather than to assume that tone as such can, in some mysterious and unexplained way, bring these changes about directly.

It can thus be seen that certain aspects of music - its possession and communication of meaning and its arousal of feelings and emotion - are linked with the mental processes. Meyer (1956) writes that "without thought and memory there could be no musical experience". There are a number of findings on mental processing based upon a wealth of empirical data. In particular,the current trend in the literature is to establish parallels between principles of visual perception (such as the Gestalt principles of continuation, closure, the law of Pragnanz) and the structure of music. For example, several studies have explored the perception of melodies that have been distorted in several ways (eg. Dowling, 1972 & 1977; Aaronson, 1971). Other studies include rhythm aspects of music (eg. Gabrielsson, 1973). Meyer (1956) gives detailed analyses of both melodic continuation and closure and rhythmic continuation and closure.

In addition, parallels between psycholinguistics and music have been established in various attempts to apply the concepts of "meaning" and "grammar" to music (eg. Lindblom & Sundberg, 1970 & 1976). A further trend borrowed from the study of language is found in various attempts to apply the concept of categorical perception as postulated by Liberman (1967) in the field of speech perception to musical perception. For example, Deutsch (1969) established a tendency to group music intervals and triads into categories such as thirds and fourths. Allen (1967)'s findings on music experience and increased awareness of the categorizations and Creelman, Kaplan & Macmillan (1977)'s study on the psychophysics of categorical perception provide further proof of the tendency to categorize.

In this study, an auditory illusion closely linked with musical perception is of particular interest. There is research on auditory anomalies within psycholinguistics, particularly within the field of phoneme perception (eg. Liberman, 1967) has received considerable attention. In addition, research in psychoacoustics and auditory perception generally has revealed the presence of auditory illusions (eg. Deutsch, 1969). Typical of these studies is an experiment by Waren & Waren (1970) who obliterated phonemes from words in a sentence by a cough or other extraneous sound and found that they were always restored. Even when subjects were told that something was missing, they could not identify the location of the extraneous sound and thereby identify the missing phoneme. They also reported illusory changes in words repeated over and over, distorting what was heard in a way that was unpredictable, unlike for example, the Necker cube reversal. Children, young adults and older people appeared to employ different mechanisms appropriate to their familiarity with language. Young adults were found to group sounds only in ways permitted in the English Language, but nonsense syllables were also reported. Older people on the other hand, only reported meaningful words. However, they also always distorted a meaningless stimulus to a meaningful one for example, "FLIME" to "SLIME" and they would stick to this illusory but sense-making word.

Ability to impose meaning has been found to vary according to prior experiences and interestingly, the more abstract and remote the connection between what is given and the meanings/ideas with which they may be associated, the greater and more prolonged the effort to understand and utilize it. It would also not be too presumptious to say that this ability to impose meaning is related to the attentional state of the perceiver.

Studies of pitch perception have indicated perceived pitch to vary with attentional factors. Significant day to day variation in subjects' judgements of pitch have been reported by Ward (1954), and Elfner (1964) reported that subjects deprived of sleep required a five percent increase in frequency separation before two tones would be judged to be an octave apart.

An effect in which attentional factors play a large part in determining the pitch sensation evoked by a tone has been demonstrated by Simmonds (1978). It is as follows: A rapidly rising and falling broken chord is accompanied by a tone of fixed pitch tuned to the tonic of the broken chord as shown in Figure I.

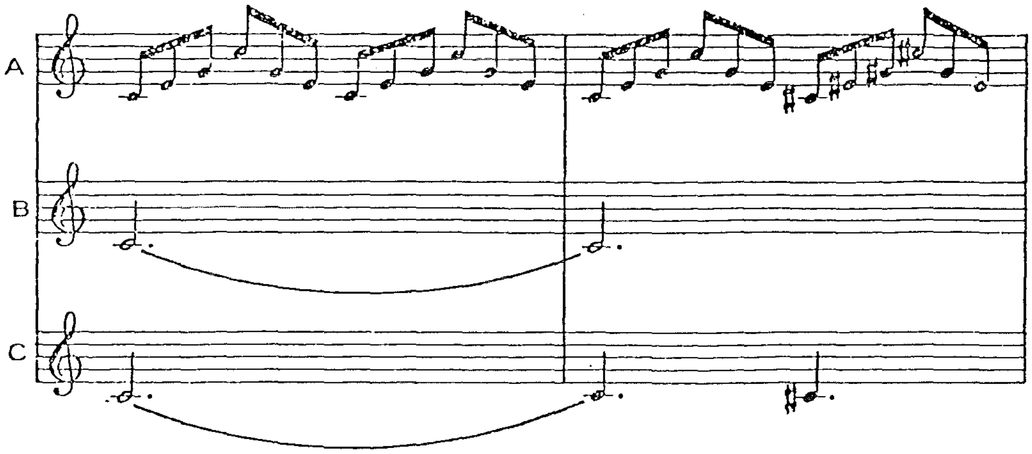

FIGURE I MISPERCEIVED PITCH OF A CONSTANT TONE

A - continuously rising and falling broken chord raised one semi-tone on every fourth presentation.

B - constant tone as presented.

C - constant tone with perceived shift in pitch.

When the pitch of the broken chord is raised a semi-tone, the fixed tone undergoes an apparent increase in pitch although its actual frequency remains constant. Apparently, the ear "re-tunes" the fixed tone to keep it consonant with the changes in pitch of the broken chord.

The generality of this phenomenon was established by Densem (1977) on a group of twenty four subjects, twelve of whom were trained musicians employed either as music teachers or performers; the remainder were music listeners with little or no formal musical training. The effect was investigated over two frequency ranges - a change in pitch of the broken chord that spanned either the octave 150-300Hz or the octave 600-1200Hz. All twenty four subjects reported the illusion. Pitch changes of up to a semi-tone were recorded. There was no systematic tendency for non-musicians to report pitch changes of different magnitude from those reported by musicians; nor did the frequency range within which the effect was preserved, affect the mean ratings of perceived pitch change.

The role of attention in this effect was implicated by a number of informal observations made on small groups of subjects. Variables included the form of presentation of the tones (eg. dichotic as opposed to monaural), loudness level of the tones, timbre and frequency of the tones. With respect to these observations, the phenomenon is undeniably robust without overlooking the strong implication of the important role of attention.

The aim of the present study is to make a formal study of the role of some of the attention-related variables as mentioned above in the phenomenon. This study is constructed very similarly to the Simmonds Study (1978). Simmonds noted that judges less frequently reported a pitch change under dichotic presentation in which the broken chord was presented to one ear and the constant tone to the other. However, no details are provided, so the effects of this variable also need to be quantified. One possibility is that dichotic presentation makes it easier for the subject to selectively attend to the constant tone because it is localized at a different point in auditory space from the arpeggio. We might also predict an interactive effect between loudness of the constant tone and dichotic vs monaural presentation such that less pitch shift is observed with loud monaural presentation than with soft dichotic presentation.

Informal observations reported in the previous study indicated that under dichotic presentation in which the broken chord was presented to one ear and the constant tone to the other, reports of a pitch change were less frequently made by subjects. This effect was examined more systematically in the present study by comparing the results obtained under a carefully controlled dichotic presentation and monaural presentation of the tones.

The earlier research suggested that the difference in loudness between the constant tone and the broken chord may be critical. If the tone was louder than the broken chord, the effect seemed to disappear and no pitch change was reported. Presumably, the influence of both stereophonic presentation and increased loudness of the tone enabled the subjects to attend more closely to the constant tone, thus eliminating the subjective pitch shift. Loudness of the constant tone then would appear to be a variable whose effects could be further explored and quantified.

Furthermore, it was considered useful to explore the illusion over two different frequency ranges. Accordingly, two ranges of frequency were included in the present study. The low ranged from 100-200Hz and the high ranged from 1000-2000Hz. In this study, both the broken chord and constant tone were always presented in the same frequency range. That is, the constant tone was tuned to the frequency of the lowest note in the arpeggio or broken chord.

Simmonds had made no attempt to quantify the degree of subjective change in pitch but informally reported that the fixed tone was "re-tuned to keep it consonant with the changes in pitch of the broken chord". Therefore some attempt will be made in the present study to quantify the degree of pitch shift by producing small actual shifts up to a semi-tone in size. The subjects on any trial will have no advanced knowledge of whether the "constant" tone changes in pitch or not on each trial.

It has also been reported that by switching their attention to the constant tone, subjects could reduce or eliminate the tendency to hear a pitch change in the constant tone when the broken chord was raised or lowered in frequency. This again implicates attentional factors as playing an important part in the illusion.

CHAPTER II

MATERIALS AND METHODS

1. HYPOTHESIS

As mentioned in Chapter I, loudness of the constant tone appears to be an important determinant of the magnitude of the illusion. The role of loudness as a factor influencing attentional processes was mentioned. The effect of dichotic vs monaural presentation was also mentioned. Three hypotheses were tested in the present study:

Hypothesis 1

Increases in the loudness of the constant tone will lead to a reduction in the perceived pitch-change of this tone.

Hypothesis 2

Monaural presentation of the constant tone and the arpeggio will result in a larger perceived pitch-change than is the case for dichotic presentation.

Both of these hypotheses are concerned with the manipulation of the ease with which the subjects can attend to the pure tone as an element within the total auditory pattern.

The frequency range of the arpeggio is also thought to be of some significance. By choosing a frequency range near the middle of the musical spectrum we might expect a more pronounced illusion than if we use a frequency range low in the spectrum, where melody is less often present.

Hypothesis 3

The perceived pitch-change will be more pronounced with an arpeggio in the range 1000-2000Hz than in the range 100-200Hz.

2. SUBJECTS

Twenty adult volunteers served as subjects; sixteen of these were either university or polytechnic students; the remaining four were in full-time employment. There were 10 females and 10 males. Ages ranged from seventeen years to thirty-nine years with the modal age being twenty-two years. Only two of the subjects were left-handed.

The sample included both sophisticated listeners (i.e. those having little or no formal training but were reasonably knowledgeable and keen listeners) and naive listeners (i.e. those having no formal training and little interest in music).

3. PROCEDURE

(a) Tape

Using equipment to be described later, a master stereophonic tape was constructed. Two frequency ranges were chosen for study. The low frequency range (LFR) spanned 100-200Hz, while the high frequency range (HFR) spanned 1000-2000Hz. That is, in the LFR the constant tone was set to 100Hz while the arpeggio consisted of a major chord based on the same frequency of 100Hz (see Figure 1). Similarly, with the HFR, the constant tone set at 1000Hz was paired with an arpeggio ranging from 1000Hz to 2000Hz.

In both the LFR and HFR, the frequency of the constant tone which otherwise had a fixed pitch tuned to the tonic of the arpeggio, was manipulated from a 0% change to a 6% change in increments of 1½% which therefore yielded five frequency changes (i.e. 0%, 1½%, 3%, 4½%, 6%). For example, in the LFR, a 1½% change in frequency represents 1.5 Hz. These randomized frequency changes (i.e. pitch changes) were made to coincide with the part of the arpeggio where it was raised a semi-tone (see Figure 1).

The loudness of the constant tone was varied over four levels. These changes in loudness were produced at the time of recording by setting the voltage units meter of the TEAC tape recorder to 100%, 80%, 60% and 40% of optimal recording level. These levels correspond to 0 dB, -2 dB, -4 dB, -8 dB below optimal recording level. This method was used to ensure that the relative loudness difference between constant tone and arpeggio preserved regardless of actual playback level set for individual subjects on the amplifier. There were therefore twenty different pairings. Because there were two frequency ranges, the subjects had forty pairings to respond to.

The master tape was synthesized on-line using a PDP 11/10 computer linked through a locally designed and built interface. This interface has been documented elsewhere (Bell, Gregson & Kennedy, 1978). In general terms it takes digital output and converts it to a linear series of stepwise increments in voltage, through two digital to analog converters. These two separate outputs of stepwise increments in voltage can be fed to various pieces of laboratory equipment under the control of a computer program. By feeding the voltages in through the input amplifiers of an EMS SYNTHI AKS and patching them to a pair of voltage-controlled oscillators in the SYNTHI, musical tones on any equal-stepped scale can be produced. For example, approximately 6½ octaves, starting from any preselected frequency in the range 50Hz to 10,000Hz can be produced by tuning the input amplifier of the SYNTHI to yield an equal temperament scale. Thus, successive integers generated in a BASIC program can be made to yield successive notes of the well-tempered chromatic scale.

However, some difficulty was experienced with drifts of up to 5% in frequency over a 20 minute period in the SYNTHI oscillators. Thus, frequent re-tuning of the oscillators was required. This was done using a Marconi TF 2414 counter/timer. Because of this inherent drift, it was decided not to run the actual data-gathering on-line, but instead, to make up a master tape for presentation to subjects. In addition, extremely accurate tuning of the constant tone was desired since this was to be varied over small increments in frequency of 2½%. Therefore an Interstate Electronics Corporation F 34 function generator, which exhibits for greater stability, was used. It was voltage-controlled by the PDP 11/10, to provide the small frequency changes used for the constant tone. A special input amplifier was built to bring the voltages generated by the computer into the required range for controlling the function generator.

The tape was synthesized on-line using a computer program written in BASIC (see Appendix I), the arpeggio and the constant tone were recorded on two separate tracks of a TEAC A 33405 4-channel simul-sync tape deck, using ¼ inch Hitachi LO-D tape, recorded at fifteen inches per second.

Five pairings from each frequency range were used as practice trials. Hence, a tape of fifty trials was constructed with the practice trials at the beginning to ensure that the subjects had understood what they had been instructed to do and to familiarize them with the scoring system employed. It was considered advisable to make the minimum necessary time available for the subject to record his/her response because an immediate response was desired and it was essential to ensure that previous responses were not changed during the course of the experiment. The trial order on the tape was set out on the score sheet as shown in Appendix II but this information was not available to the subjects. There was a brief interval of 2.5 seconds between each trial for scoring. A 5-point response scale was used. Appendix III explains how responses were to be rated.

(b) Test

Subjects listened to the tape one at a time. They were seated with their backs facing the tape recorder to avoid distraction. Headphones were used to standardize listening conditions (at a comfortable loudness level). They also reduced the possibility of further distraction.

Written instructions to the subjects were standardized by providing both a description of the situation, and what was required of them in terms of their responses (see Appendix IV). With the aid of the practice trials subjects readily grasped what was required of them. It was pointed out that they may experience a subjective change and that it was not a test in the sense that there were no correct answers but they were to respond with their immediate impression. The trials were then run through without stopping.

The first forty trials were presented dichotically. There was a short break to rewind the tape and for the subjects to have a break from the monotony. The trials were run through again, this time presented monaurally. In all, each subject went through a total of eighty trials. The whole procedure took between thirty to forty-five minutes.

CHAPTER III

RESULTS

Although ANOVA is not entirely appropriate as a means of analysing these results, because the range of responses on the 5-point scale is generally small, it is desirable to examine some of the interactions between some of the factors that represent attempts to measure the role of attentional processes in the illusion. For example, we have noted that the loudness factor might interact with the monaural vs dichotic presentation. Therefore this interaction in particular is of interest.

The data were therefore cast into a 4-way analysis of variance with repeated measures on all four factors. The factors are:

(1) A - loudness of the constant tone, relative to the arpeggio. There are four levels yielding a_1, a_2, a_3 & a_4 where

a_1 = 0 dB below optimal recording level
a_2 = -2 dB below optimal recording level
a_3 = -4 dB below optimal recording level
a_4 = -8 dB below optimal recording level
(These values were set on the voltage unit meters of the TEAC tape recorder at the time of recording the master tape)

(2) B - frequency changes of the constant tone. There are five changes yielding b_1, b_2, b_3, b_4 & b_5 where

b_1 = 0 %
b_2 = 1½ %

b_3 = 3 %

b_4 = $4\frac{1}{2}$ %

b_5 = 6 %

(These values are percentage increases in frequency of the constant tone, expressed as a percentage of the frequency of the lowest note in the arpeggio. Thus, for example, if the lowest note was 100Hz, a 3% increase in frequency would be 3% of 100, yielding a frequency of 103Hz for the constant tone)

(3) C - frequency range of the arpeggio. There are two ranges yielding c_1 & c_2 where

c_1 = high (1000 - 2000Hz) range

c_2 = low (100 - 200Hz) range

(4) D - mode of presentation. There are two modes yielding d_1 & d_2 where

d_1 = monaural presentation (arpeggio and constant tone present in both ears)

d_2 = dichotic presentation (arpeggio in one ear, constant tone in the other)

A 4-way ANOVA was conducted using BMD08V from the BMD package. The results of this analysis are summarized below in Table I.

TABLE I RESULTS OF THE 4-WAY ANOVA

SOURCE	SS	df	Ms	F	
A	8.9150	3,57	2.9716	5.5563	**
B	440.5788	4,76	110.1447	87.2467	**
C	150.0625	1,19	150.0625	64.3065	**
D	1.9600	1,19	1.9600	1.3522	
AB	22.2512	12,228	1.8534	5.0468	**
AC	2.5225	3,57	0.8408	1.4667	
BC	7.1937	4.76	1.7984	2.7319	*
AD	1.1150	3,57	0.3716	0.9815	
BD	25.2587	4,76	6.3397	15.0491	**
CD	3.0625	1,19	3.0625	3.6282	
ABC	15.7462	12,228	1.3122	3.3268	**
ABD	4.1912	12,228	0.3493	1.0800	
ACD	1.1825	3,57	0.3942	0.6743	
BCD	4.3.87	4,76	1.0797	2.6086	*
ABCD	3.1112	12,228	0.2593	0.7777	

* Significant at the 0.05 level

** Significant at the 0.01 level

The F values for factor D was found to be insignificant suggesting that the mode of presentation did not have any effect on the perception of the constant tone. Factors A, B and C were found to be significant suggesting that loudness and frequency changes were indeed perceived and that different frequency changes had an effect on the perception of the constant tone. Note that the interactive effects of AB, BC, BD and ABC were significant whereas AC, AD, CD, ABD, ACD, BCD and ABCD were insignificant. This is presumably due to the large main effect associated with the B-factor.

To establish which pairs of means differed significantly on the B-factor, t-tests (repeated measures) were carried out as follows:

For	b_1 and b_2	$t_1 = 8.273$ **
	b_2 and b_3	$t_2 = 3.275$ **
	b_3 and b_4	$t_3 = 4.522$ **
	b_4 and b_5	$t_4 = 0.549$

** Significant at the 0.01 level with 19 degrees of freedom

t_1, t_2 and t_3 yielded significant values whereas t_4 did not. This could mean that beyond a frequency change of 4½% in the constant tone, the perceived pitch shift tended to remain the same.

t-tests were also carried out on the A-factor:

For	a_1 and a_2	$t_1 = 0.379$
	a_2 and a_3	$t_2 = 3.227$ **
	a_3 and a_4	$t_3 = 2.665$ *

* Significant at the 0.02 level with 19 degrees of freedom

** Significant at the 0.01 level with 19 degrees of freedom

t_2 and t_3 yielded significant values whereas t_1 did not. This could mean that a certain threshold must be reached before the perceived changes have any significance.

There are some difficulties in using ANOVA with the data obtained in this study because of the restricted range of the dependent variable on a 5-point category scale.So some additional non-parametric analyses were conducted in order to clarify some of the trends found in the ANOVA.

The Wilcoxon matched-pairs signed-ranks test was used to test whether there was any difference in obtained scores between high and low frequency ranges. It was chosen because the study was of a repeated measure design and yielded difference scores which may be ranked in order of absolute magnitude. The hypotheses are:

(1) H_0: no difference between high and low frequency ranges. In terms of the Wilcoxon test, the sum of the positive ranks equal the sum of the negative ranks.

(2) H_1: the obtained scores for high and low frequency ranges differ i.e. the sum of the positive ranks do not equal the sum of the negative ranks.

Since the direction of the difference is not predicted, a two-tailed region of rejection is appropriate. The region of rejection consists of all values of T which are so small that the probability associated with their occurrence under H_0 is equal to or less than $\alpha = 0.05$ for a two-tailed test.

TABLE II RESULTS OF THE WILCOXON TEST

MONAURAL HIGH/LOW	T = 0
DICHOTIC HIGH/LOW	T = 5.5

Appendix V (from Siegel, 1959) gives critical values from the sampling distribution of T, for $N \leq 25$. With N = 20, $T \leq 52$, we may reject the null hypothesis at $\alpha = 0.05$, for a two-tailed test. Therefore, we reject H_o in favour of H_1, concluding that there is a difference in obtained scores between high and low frequency ranges.

In taking a test score of 0 to mean that no change was perceived a two-category class situation was produced, thus, enabling the use of the binomial test to test for perceived change in the constant tone. A one-tailed test was used as it could be predicted in advance which of the two categories will contain the smaller number of cases. The hypotheses are:

(1) H_o: $p_1 = p_2 = \frac{1}{2}$ i.e. there is no difference between the probability of hearing the change (P_1) and the probability of not hearing the change (P_2); any difference between the frequencies which may be observed is of such a magnitude that it might be expected in a sample from the population of possible results under H_o.

(2) H_1: $p_1 > p_2$.

The sampling distribution is given in the following formula:

$$\sum_{i=0}^{x} \binom{N}{i} P^i Q^{N-i} \qquad \text{where}$$

N = sample size

P = proportion of cases expected in one of the categories

Q = 1 - P

x = number of subjects who scored 0

However, when $N \leq 25$ and when $P = Q = \frac{1}{2}$, Appendix VI (from Siegel, 1959) gives the probabilities associated with the occurence under H_o of observed values as small as x_1 and thus obviates the necessity for using the sampling distribution directly in the employment of this test.

The region of rejection consist of all values of x which are so small that the probability associated with their occurence under H_0 is equal or less than $\alpha = 0.001$. The data are shown below:

TABLE III RESULTS OF BINOMIAL TEST

III (a)

			a_1	a_2	a_3	a_4
$b_1 = 0\%$	Monaural	HFR	0.000	0.000	0.001	0.006
		LFR	0.058	0.058	0.021	0.006
	Dichotic	HFR	0.132	0.001	0.588	0.001
		LFR	0.748	0.748	0.748	0.979

III (b)

			a_1	a_2	a_3	a_4
$b_2 = 1\frac{1}{2}\%$	Monaural	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.00	0.001
	Dichotic	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.021	0.00

III (c)

$b_3 = 3\%$			a_1	a_2	a_3	a_4
	Monaural	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.00	0.00
	Dichotic	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.00	0.00

III (d)

$b_4 = 4\frac{1}{2}\%$			a_1	a_2	a_3	a_4
	Monaural	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.00	0.00
	Dichotic	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.00	0.00

III (e)

$b_5 = 6\%$			a_1	a_2	a_3	a_4
	Monaural	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.00	0.00
	Dichotic	HFR	0.00	0.00	0.00	0.00
		LFR	0.00	0.00	0.00	0.00

$\underset{i=4}{a_i}$ = loudness levels

$\underset{i=5}{b_i}$ = frequency changes

To accept H_o, $P_i \geqslant 0.01$

The results of Table III (a) indicate that for tones presented monaurally, the subjects heard an apparent change (i.e. heard the illusion since at b_1 the frequency change was 0%) in the constant tone at all levels of loudness in the HFR. They did not hear it in the LFR (except at a_4, i.e. loudness level 4).

For tones presented dichotically, the results indicate an inconsistent perception of the illusion for tones presented in the HFR. At a_1 and a_3, H_0 was not rejected and at a_2 and a_4, H_0 was rejected. The results produced by the LFR do not allow rejection of H_0 at all levels of loudness.

The results of Tables III (b), III (c), III (d) and III (e) indicate that the subjects heard a change in the constant tone whether the tones were presented monaurally or dichotically, over the high or low frequency range and at any level of loudness. Out of these values, there is however one value in Table III (b) which indicated that subjects did not hear a change in the constant tone at loudness level 3 with frequency change of 1½% in the constant tone. Subjects were expected to hear a change (as indicated by results in Tables III (b), III (c), III (d) and III (e)) as there are actual frequency changes of 1½%, 3%, 4½% and 6% respectively in the constant tone. The results here indicate that loudness level, mode of presentation and frequency range do not affect the perception of a concrete change in the constant tone. Where the change is apparent i.e. illusionary, the loudness level, mode of presentation and frequency range within which the constant tone was presented, is seen to play an important role.

From the results in Table III(a), it can be inferred that low frequency changes diminish the ability to perceive the illusory change in the constant tone. In fact, the subjects' verbal reports confirmed that changes could be more easily identified in the high frequency range. This supports the results obtained for the monaural mode of presentation. The contradicting results for the dichotic mode of presentation are difficult to explain.

The results of the ANOVA are presented graphically in Figures II (a) & (b), III (a) & (b), IV (a) & (b) and V (a) & (b). The main effects means appear in Table IV.

TABLE IV MAIN-EFFECTS MEANS FROM ANOVA

FACTORS	LEVELS 1	2	3	4	5
A	2.0550	2.0325	1.8625	1.9700	
B	0.9781	1.9687	2.1750	2.4000	2.3781
C	2.2862	1.6737			
D	2.0150	1.9450			

These results indicate that loudness, mode of presentation and frequency range affects the degree of perceived pitch-shift in the following way:

Louder levels decreased it.

Dichotic presentation decreased it.

Low frequency range decreased it.

These results are as predicted under the assumption that these variables are attention-related.

The results obtained for factor B are as predicted since increased frequency changes should increase the degree of perceived pitch shift.

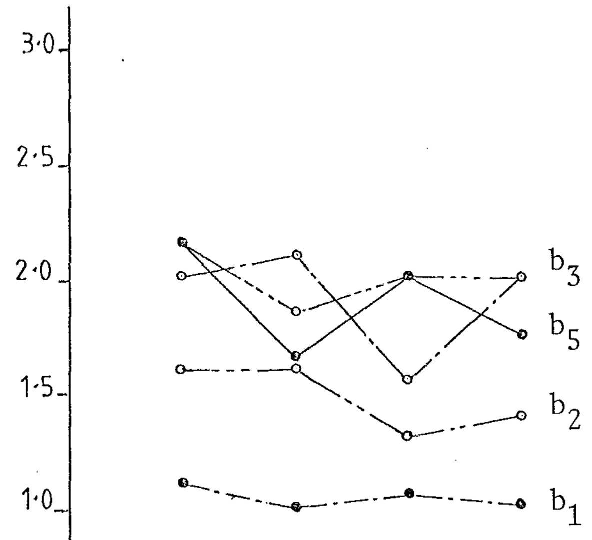

Figure 2(a) Interaction between frequency change and loudness for monaural presentation in the low frequency range (100-200Hz)

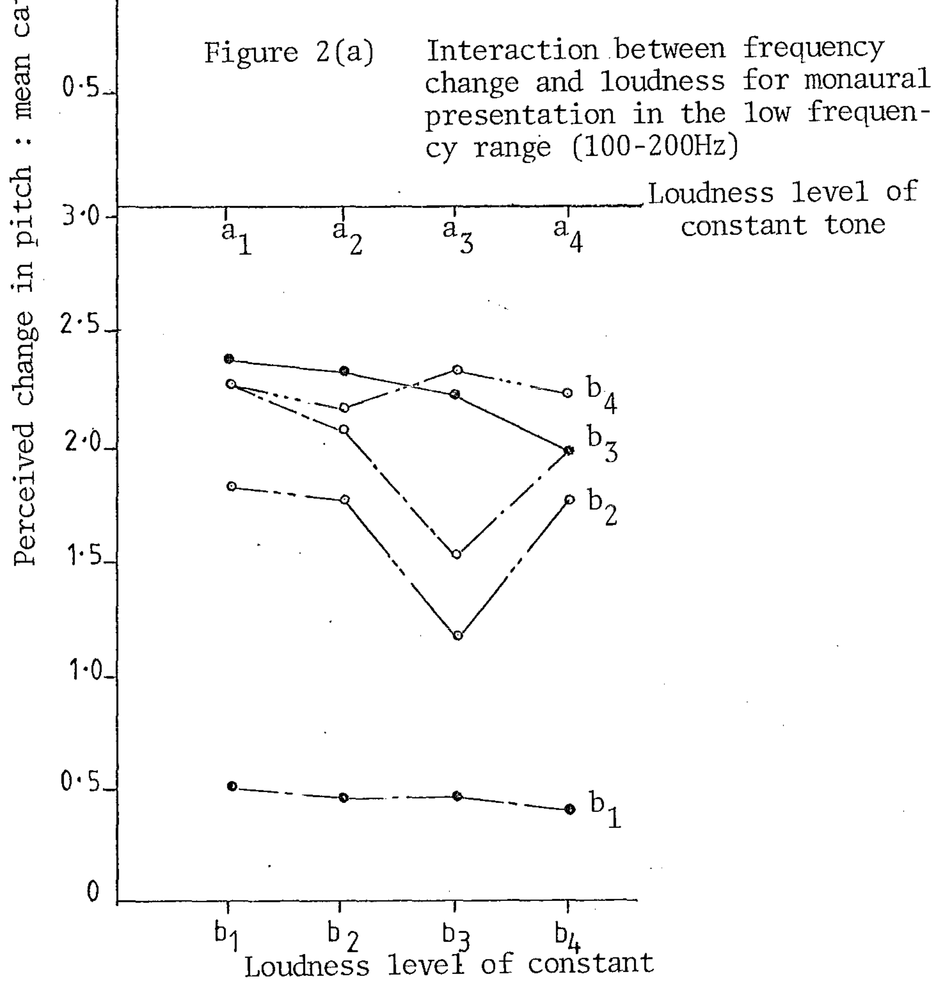

Figure 2(b) Interaction between frequency change and loudness for dichotic presentation in the low frequen- range (100-200Hz)

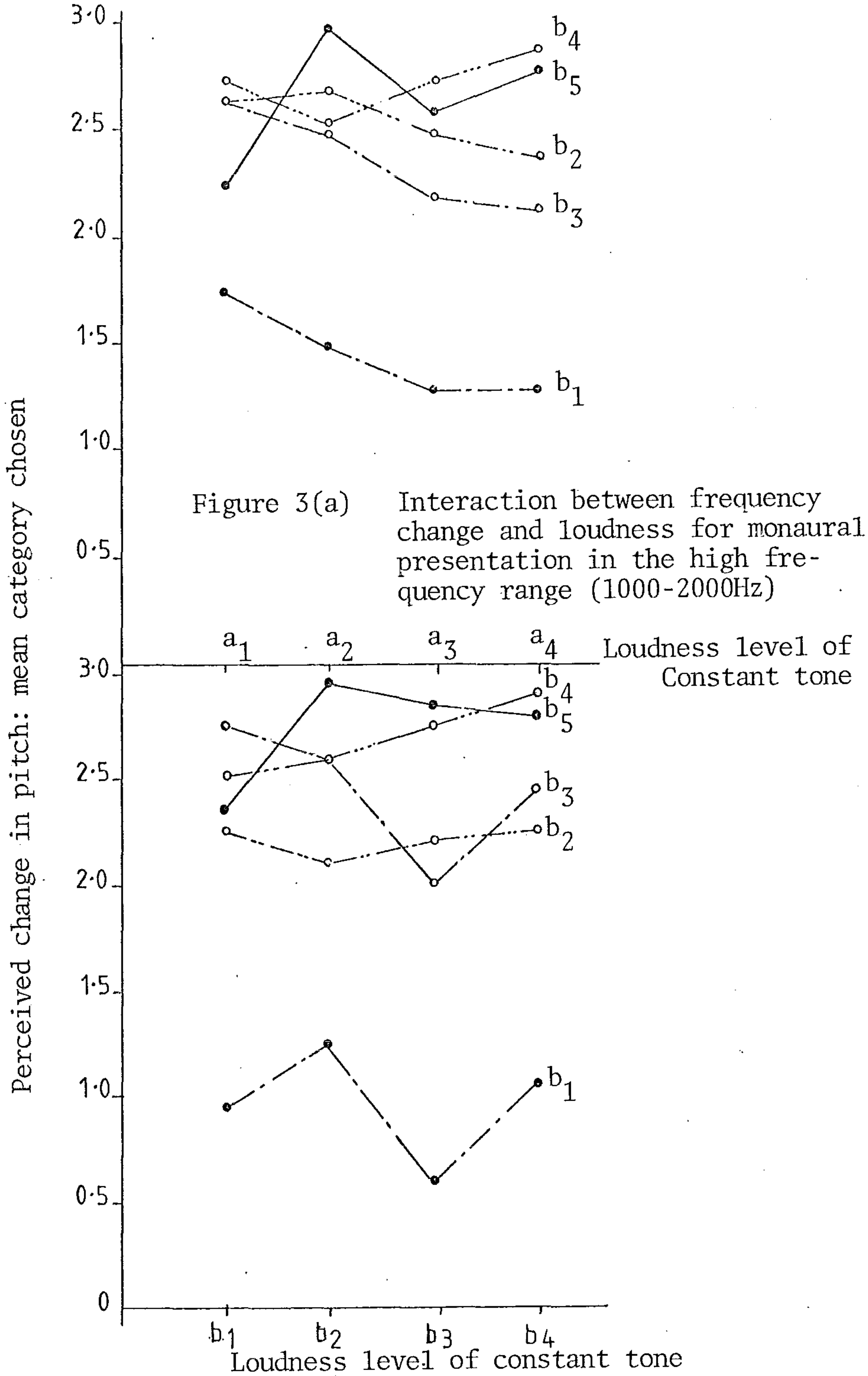

Figure 3(a) Interaction between frequency change and loudness for monaural presentation in the high frequency range (1000-2000Hz)

Figure 3(b) Interaction between frequency change and loudness for dichotic presentation in the high frequen- range (1000-2000Hz)

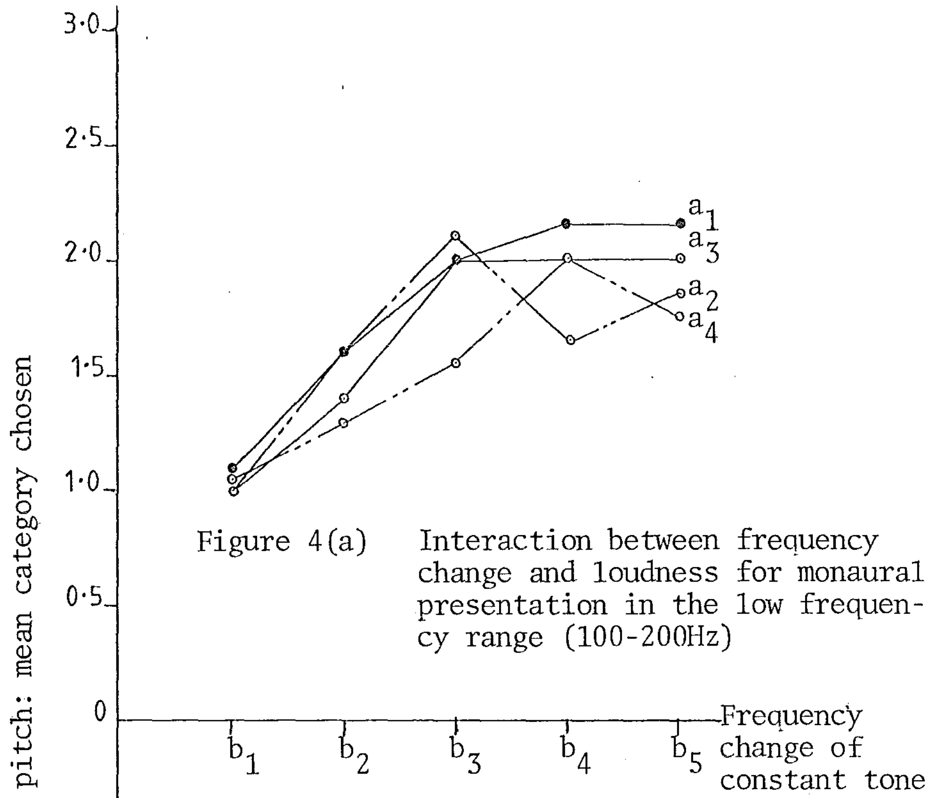

Figure 4(a) Interaction between frequency change and loudness for monaural presentation in the low frequency range (100-200Hz)

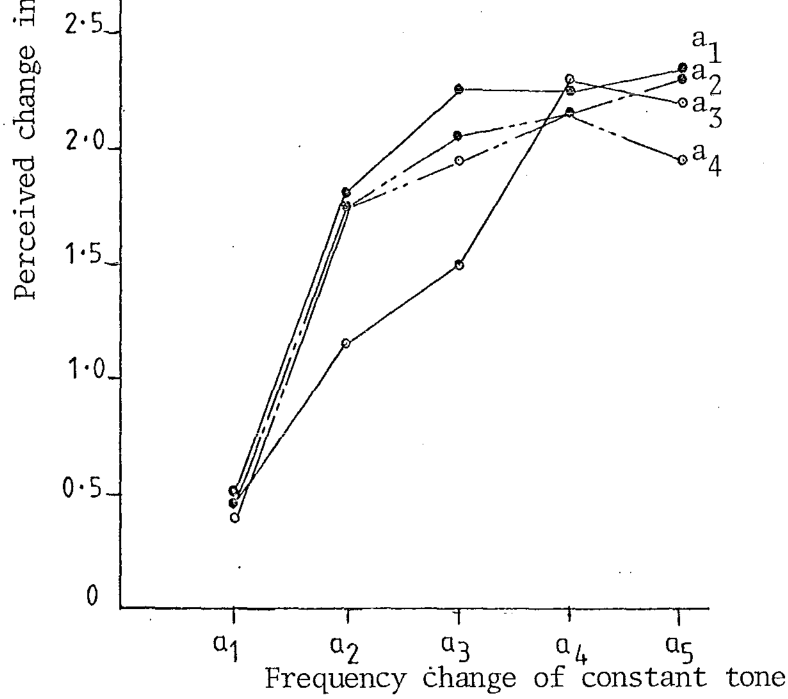

Figure 4(b) Interaction between frequency change and loudness for dichotic presentation in the low frequency range (100-200Hz)

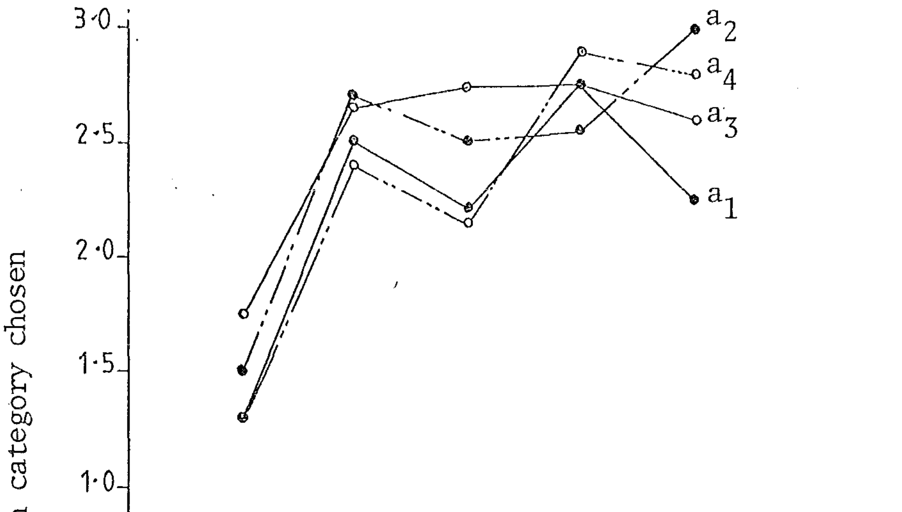

Figure 5(a) Interaction between frequency and loudness for monaural presentation in the high frequency range (1000-2000Hz)

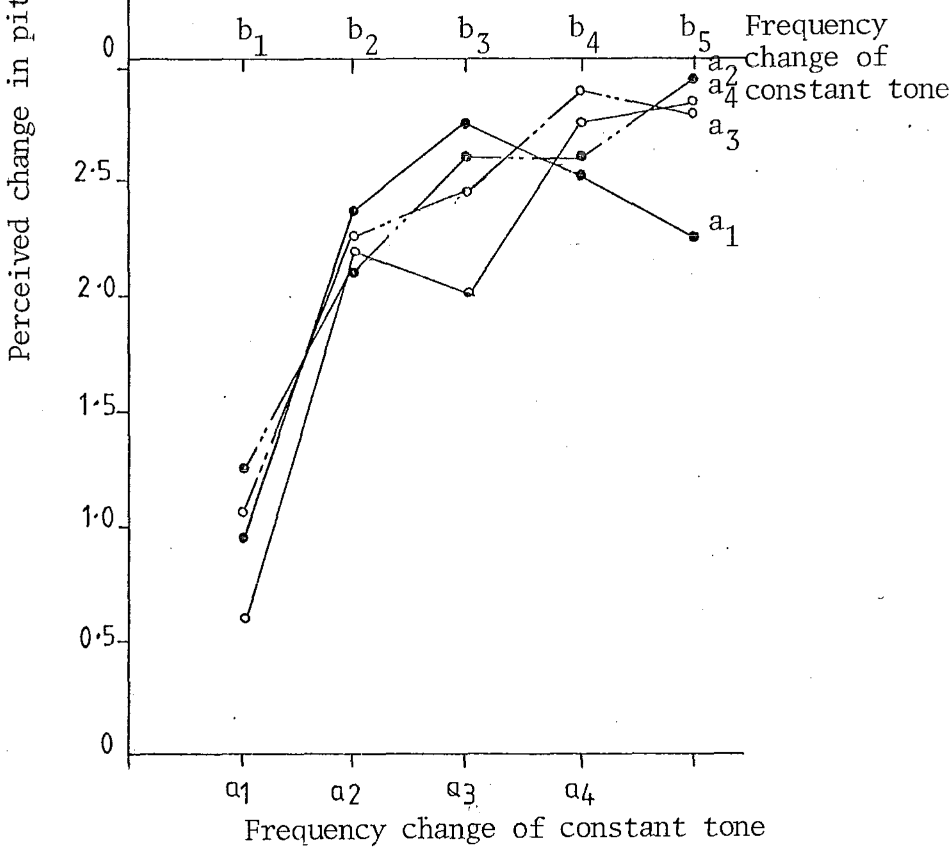

Figure 5(b) Intereaction between frequency and loudness for dichotic presentation in the high frequency range (1000-2000Hz)

It has been tentatively established (Simmonds, 1978) that the illusion studied here is not simply a consequence of using pure tones - the effect is reported to occur with complex timbres as well. Further research is needed to establish whether the effect derives from musical perception or whether it is a purely auditory phenomenon. For example, a complex wave such as a square wave could be used in place of the arpeggio to see if the illusion still persists. We have adopted the approach in this study that attentional factors play a large part in the perception of this illusion. By manipulating loudness of the constant tone (under the assumption that a louder tone is easier to attend to) and also by manipulating dichotic vs monaural presentation, (under the assumption that dichotic presentation makes it easier to attend to the constant tone because it can be more easily localized in space) we hoped to partial out the effect of attention.

The loudness manipulation has affected the illusion as hypothesized (see Figure II & III). The effect of dichotic vs monaural presentation is less clear-cut. The means show a decrease from the monaural to the dichotic situation (see Table IV), suggesting a trend for the illusion to be less noticeable under stereophonic presentation. Again, it is easier to attend to sounds that are separated in space and so this trend fits with the attention hypothesis.

CHAPTER IV

DISCUSSION

We can conclude from this study that the illusory experience resulting from the conditions described in this study is a robust phenomenon and dependent upon the attentional state of the observer. Evidence that the attentional mechanism plays a part in the illusion has prompted the writer to adopt an information processing approach in discussing and analysing the results.

The literature on attention indicates that a limited capacity processing occurs in many situations, for example, when we first learn to drive a car, we cannot both drive and talk, and the task of driving seems difficult and mentally tiring. Later on, driving experience reduces the attentional demand required and we can drive, talk, sing and still have excess capacity. Dowling (1973) provides another example: When pairs of melodies were presented, his subjects reported that they could only attend to one melody with the other as background but not to both simultaneously. This is in part the reasoning underlying the use of dichotic/monaural presentation and loudness as variables in this study. In addition, the presence of the dichotic (or stereophonic) cue provides a spatial separation of the constant tone from the arpeggio. This makes it easier for the subject to selectively attend to the constant tone as distinct from the arpeggio - hence attentional factors are implicated.

The results indicated that the difference in loudness between the constant tone and the arpeggio was critical. If the tone was louder than the arpeggio, the effect disappeared and no pitch-change was reported (see Table IV). Presumably, the increased loudness of the constant tone enabled the subjects to attend more closely to the constant tone thus eliminating the subjective pitch shift. The dichotic presentation of the stimuli in which the arpeggio was presented to one ear and the constant tone to the other, was expected to affect the subjects' perception of the subjective pitch shift in a similar fashion. The results obtained from the binomial test provide some support for this. The effect was observed to be very consistent under the monaural high frequency presentation, whereas it was observed to be less consistent under the dichotic high frequency presentation. A similar trend was expected in the results under the low frequency presentation. However, that was not found. The subjects failed to report the effect under the monaural low frequency presentation. While it could be presumed that stereophonic presentation enabled the subjects to attend more closely to the constant tone, thus eliminating the subjective pitch shift, the frequency range in which the tone occurs seems to have some significance in the perception of the effect.

Studies have indicated that higher and louder frequencies capture attention better than lower and softer frequencies (eg. Broadbent, 1958). This provides an explanation of the above results. Subjects found it easier to hear the pitch-change during the high frequency presentation. They reported that it was hard to distinguish any pitch-changes when the tones were presented in the lower frequency range. This was the case when the subjects responded to the monaural mode of presentation. On the dichotic mode, the subjects did not show the same confidence as the results indicated that they heard the pitch-change only at two loudness levels. Presumably, the effect of dichotic presentation was too strong to overcome at times, thus making it harder to perceive the pitch-change even during the high frequency presentation.

So far, the writer has only dealt with the attention-related variables. The occurrence of the illusion strikes the writer as a very interesting phenomenon and she will discuss it with reference to the findings of the studies reviewed in the introduction.

It seems reasonable to the writer to assert that music is comparable to language. They are both used to communicate "information"; they are a result of social processes; they have structure - the list is endless. Being related to information processing, they share something in common with vision. It does not then seem out of line to give a vision-based or a language-based analogy of the phenomenon we have seen here.

Language provides a structural context, the degree of its familiarity affecting what words we hear. Similarly, visual illusions such as the distortions of schematic drawings and the reduced ability to impose meaning as they become further removed from everyday experience of perspective cues, arise from our knowledge of objects which provides the structure for interpreting what we see. The common denominator for experience to exert an effect is that possibilities exist for cognitive structure to be imposed on sensations, and opportunities be available for each person to acquire a different set of schema to use, thus leading to differences in perception. Similarly, music provides a structured context within which sounds can be made meaningful and therefore, analogously, differential experiences of music are surely likely to affect what sounds we hear in a musical context. For example, the listener who knows the typical pattern of recurrences of a theme in a fugue, a rondo, a sonata, a Balinese dance or an Indian Raga is able to perceive the musical structure more easily than the listener who does not know what to expect (Dowling, 1973). Thus, context has a very important role to play in illusory perception. In the cases where the percept does not seem to fit into any particular context, there is a tendency to manipulate it in such a way that it fits. Studies have been quoted in the introduction to support this contention.

An alternative line of reasoning is that the perceived illusion may be related to the categorical mode of perception. Speech is replete with perceptual categories, as much research at the Haskins Laboratories has shown (see Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967; Liberman, Harris, Hoffman & Griffith, 1957; Lisker & Abramson, 1964; Pisoni, 1971 & 1973). The tendency to group music intervals and triads into categories such as thirds and fourths seem to support the existence of such a mode (Dowling, 1973).

As stated in the introduction, the more remote the connection between what is given and the meaning with which it may be associated, the greater and more prolonged the effort to understand and utilize it. This assumption could also explain the differences obtained in the high and low frequency ranges. The high frequency range may have provided a more familiar musical context, therefore when the subjects were exposed to the low frequency situation, they have been unable to extract any meaning. However, when confronted with the familiar higher tones, there may be a greater likelihood of imposing meaning on the original form of the stimulus thus, perceiving a change in the constant tone, to keep it consonant with the changing arpeggio.

There are some points of concern regarding the results. First, there is the question of whether or not the constant tone was actually heard continuously, eventhough all subjects reported they were always aware of its presence. Subjects could not tell exactly when the constant tone changed. There were times when they noticed the change only when the arpeggio changed back to the original form. In this situation, they often heard it drop with an accompanying increase in loudness which led them to score the change as more than a semitone. Deutsch & Roll (1976) reports that when two tones are presented dichotically, one ear is dominant and there is suppression of the tone in the other ear. If this is the case here i.e. if the constant tone is sometimes suppressed when the arpeggio shifts, it does not affect the foregoing analysis too much. The fact that the constant tone may be suppressed would fit in with the maintaining of consonance and there is still the illusion of change.

Secondly, the scoring procedure may have created problems. A Likert type scale of degree of sureness of change rather than degree of frequency change in the stimulus, and treating the data as ordinal rather than equal interval, may have been more appropriate.

Another problem is the use of too many frequency changes (there were five). The tiny increments may have made it harder to discriminate the degree of change, thus creating a confused state. Many subjects reported that they were never quite sure if they have scored accurately.

CONCLUSION

In this study, we have dealt with the simplest of auditory stimuli, pure tones. Why pure tones? They sound dull. Moreover, auditory stimuli eg. music and speech sounds are not made up of single pure tones. But for obvious reasons, Roederer feels that it is advisable to deal first with pure tones only for a better understanding of complex sounds.

Pure tones have to be generated with electronic oscillators; there is no musical instrument that produces them and even for electronically generated pure tones, there is no guarantee that they will be "pure" when they actually reach our ear. This is an important point to consider in studies of auditory perception using pure tones as noise can affect the perception unfavourably.

The various studies of the auditory mode eg. study of speech perception, study of music perception, study of pitch perception, all help to build a clearer picture of how our auditory system works, both psychologically and physically. There are still many gaps in the theories that have been hypothesized and to try and bridge these gaps, many approaches have been tried. A valuable way is to study errors made by the auditory system. "...the mechanics of a system are frequently revealed primarily through its errors and distortions. When all works smoothly and properly, it is difficult to know where to begin the search. But when failures occur, the analysis of those failures can be very revealing" (Lindsay & Norman, 1977).

To start with, we have the perception of combination tones. These tones are additional pitch sensations that appear when two pure tones of frequencies f_1 and f_2 are sounded together; they are most easily perceived if the latter are of high intensity level. "These additional pitch sensations correspond to frequencies that differ from both f_1 and f_2, as can be established easily with pitch-matching or pitch-cancellation experiments" (Goldstein, 1970). They are not present in the original sound stimulus - they appear as the result of a so-called nonlinear distortion of the acoustical signal in the ear. We have here an example of a mismatch between what is physically presented and what is subjectively perceived (Roederer, 1975).

Another example which is the result of only a simple pure tone presented at a very loud level are aural harmonics. They correspond to frequencies that are integer multiples of the original frequency: $2f_1$, $3f_1$, $4f_1$ etc. Again, there is a mismatch between the physical stimulus and the perceived tone.

Yet another example is the missing fundamental. The corresponding pitch sensation is called periodicity pitch, subjective pitch, residue tone or virtual pitch. This pitch is clearly distinguishable from the primary pitch of each one of the two original pure tones (also called spectral pitch). Experiments indicate that it is the result of neural processing at a higher level. For example, critical band masking of the basilar membrane does not eliminate the missing fundamental (Lindsay & Norman, 1977).

Whether the above examples could be seen as illusions is arguable. The fact that they are additional pitch sensations and do not have corresponding frequencies in the original sound stimulus indicate that we are hearing what is not there. But experiments have unfolded that they are thought to be a result of neural processing. Physically, these "illusions" occur as a consequence of the way our auditory system works. Psychologically too, "illusions" occur as a consequence of the way our auditory system works. However, results have not been conclusive. There are still too many areas of uncertainty.

SPECIALLY FOR MUM

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APPENDIX I

COMPUTER PROGRAM USED TO SYNTHESIZE THE TAPE

```
THUNG   26-JUN-81   BASIC/CAPS   VOL-01

14    DIM D(24)
15    DIM A(2)
16    REM - TWO ARPEGGIO FREQUENCY BANDS (200HZ AND 200HZ)
17    W=RND(0)\REM REPRODUCIBLE RANDOM NUMBER SETS
20    DIM B(4), C(5)
21    REM - FOUR LOUDNESS LEVELS, 5 FREQUENCY INCREMENTS
25    GOSUB 500
26    REM - RANDOMIZE FREQUENCY BANDS
100   REM - PRINT OUT THE TRIAL - BY - TRIAL SEQUENCE
120   FOR L=1 TO 2
122   PROJ (1,40)\PROJ (2,40)
125   PRINT "TUNE THE TWO OSCILLATORS TOGETHER NOW"
126   PRINT "INPUT WHEN TUNED";INPUT Y$
130   PRINT "FREQUENCY BAND"; A(L)
140   PRINT "*****************"
142   PRINT "INPUT WHEN SET TO CORRECT FREQ. BAND";INPUT Y$
145   FOR M=L TO 4\B(M)=0\NEXT M
148   GOSUB 1000
149   REM - RANDOMIZE THE LOUDNESS LEVELS
160   FOR M=1 TO 4
170   PRINT "LOUDNESS LEVEL"; B(M)
175   PRINT "INPUT WHEN LOUDNESS HAS BEEN SET";INPUT Y$
180   PRINT
```

```
190   PRINT "TRIAL NUMBERS AND FREQUENCY INCREMENTS"
192   FOR N=1 TO 5\ C(N)=0 \NEXT N
194   GOSUB 2000
195   REM - RANDOMIZE THE FREQUENCY INCREMENTS
200   FOR N=1 TO 5
210   GOSUB 5000
211   REM - COMPUTER SETS THE FREQUENCY INCREMENTS AND PLAYS THE
      ARPEGGIO
220   T=T+1
230   PRINT T; C(N)
240   NEXT N
250   PRINT\ PRINT
260   NEXT M
270   PRINT \PRINT
280   NEXT L
499   END
500   REM - RANDOMIZE FREQUENCY BANDS
502   K=0
503   REM
505   X=INT(RND(0)*2)+1
510   IF A(X)=0 THEN K=K+1
520   IF A(X)=0 THEN A(X)=K
```

```
530   FOR J=1 TO 2

FY4HP(J)=0  THEN 503
550   NEXT J
560   RETURN
1000  REM - RANDOMIZE THE FOUR LOUDNESS LEVELS
1002  K=0
1005  X=INT(RND(0)*4) +1
1010  IF B(X)=0 THEN K=K+1
1020  IF B(X)=0 THEN B(X)=K
1030  FOR J=1 TO 4
1040  IF B(J)=0 THEN 1005
1050  NEXT J
1060  RETURN
2000  REM - RANDOMIZE THE FIVE FREQUENCY INCREMENTS
2002  K=0
2005  X=INT(RND(0)*5) +1
2010  IF C(X)=0 THEN K=K+L
2020  IF C(X)=0 THEN C(X)=K
2030  FOR J=1 TO 5
2040  IF C(J)=0 THEN 2005
2050  NEXT J
2060  RETURN
5000  REM - SET THE NOTES FOR RECORDING, USING 'PROJ' FUNCTION
5005  REM SET THE ARPEGGIO
5006  PRINT "SET TAPE RECORDER TO ZERO, ETC FOR BLANK BETWEEN TRIALS"
5007  PRINT "INPUT WHEN READY" ; INPUT B$
5010  FOR H=1 TO 24
5020  READ D(H)
```

```
5030 NEXT H
5031 PROJ (2,40)
5032 FOR H=1 TO 18
5033 Z=D(H)
5034 PROJ (1,Z)
5035 FOR G=1 TO 200
5036 NEXT G \NEXT H
5040 DATA 40,36,33,28,33,36,40,36,33,28,33,36

5042 DATA 40,36,33,28,33,36,39,35,32,27,32,35
5043 REM-STEADY TONE FREQUENCY -VARIATION SELECTION
5044 RESTORE
```

APPENDIX II

SCORE SHEET SHOWING THE TRIAL ORDER ON THE TAPE

	Trial No.	Rating					Trial No.	Rating			
	1 b_5	0	1	2	3		21b_3	0	1	2	3
	2 b_4	0	1	2	3		22b_2	0	1	2	3
a_1	3 b_2	0	1	2	3	a_3	23b_5	0	1	2	3
	4 b_3	0	1	2	3		24b_4	0	1	2	3
	5 b_1	0	1	2	3		25b_1	0	1	2	3
	6 b_5	0	1	2	3		26b_5	0	1	2	3
	7 b_1	0	1	2	3		27b_1	0	1	2	3
a_2	8 b_4	0	1	2	3	a_4	28b_3	0	1	2	3
	9 b_2	0	1	2	3		29b_2	0	1	2	3
	10 b_3	0	1	2	3		30b_4	0	1	2	3
	11 b_4	0	1	2	3		31b_3	0	1	2	3
	12 b_1	0	1	2	3		32b_1	0	1	2	3
a_4	13 b_5	0	1	2	3	a_1	33b_5	0	1	2	3
	14 b_2	0	1	2	3		34b_4	0	1	2	3
	15 b_3	0	1	2	3		35b_2	0	1	2	3
	16 b_2	0	1	2	3		36b_5	0	1	2	3
	17 b_4	0	1	2	3		37b_3	0	1	2	3
a_3	18 b_5	0	1	2	3	a_2	38b_2	0	1	2	3
	19 b_1	0	1	2	3		39b_4	0	1	2	3
	20 b_3	0	1	2	3		40b_1	0	1	2	3

$\overset{4}{\underset{i=1}{a_i}}$ = loudness levels where a_1 = 0 dB

a_2 =-2 dB

a_3 =-4 dB

a_4 =-8 dB

b_j = frequency changes where $b_1 = 0\ \%$
$j=1$

$b_2 = 1\frac{1}{2}\ \%$

$b_3 = 3\ \%$

$b_4 = 4\frac{1}{2}\ \%$

$b_5 = 6\ \%$

High frequency range = trial no. 1 - 20

Low frequency range = trial no. 20 - 40

APPENDIX III

INSTRUCTIONS TO SUBJECTS

For each trial circle the number which best represents your rating of change of pitch of the constant tone as the arpeggio shifts a semi-tone.

0 - no shift at all

1 - a just noticeable change

2 - a definite change but not as much as the arpeggio

3 - same change as arpeggio i.e. very apparent

4 - more than arpeggio

PRACTICE TRIALS

Trial No.	Rating			
A	0	1	2	3
B	0	1	2	3
C	0	1	2	3
D	0	1	2	3

APPENDIX IV

AN INTRODUCTION TO THE EXPERIMENTAL SITUATION

Illusions of perception are very commonly experienced, especially those of visual perception (eg. Muller Lines, Ames Windows).What I have here deals with auditory perception - specifically the illusory pitch changes of a constant tone.

You will be simultaneously presented with two different sounds, one an arpeggio (in this case a series of tones spanning an octave), the other a constant tone.

Over a number of trials, this constant tone will be presented at four different levels of loudness. For 50% of the trials, the tones will be played in a high frequency band; for the remaining trials, they will be played at a much lower frequency.

On each trial, the arpeggio will shift a semi-tone up and down several times. Your task is to determine any changes in pitch (or frequency) in the constant tone as the arpeggio shifts while listening to both the constant tone and the arpeggio. The constant tone may vary in pitch from no change, up to the same amount of change as the arpeggio i.e. a semi-tone or more.

Your score sheet has intructions on how to score your responses. Practice trials will be given to enable you to become accustomed to the task and the use of the scoring system.

APPENDIX V

TABLE OF CRITICAL VALUES OF T IN THE WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

N	Level of significance for one-tailed test		
	.025	.01	.005
	Level of significance for two-tailed test		
	.05	.02	.01
6	0	—	—
7	2	0	—
8	4	2	0
9	6	3	2
10	8	5	3
11	11	7	5
12	14	10	7
13	17	13	10
14	21	16	13
15	25	20	16
16	30	24	20
17	35	28	23
18	40	33	28
19	46	38	32
20	52	43	38
21	59	49	43
22	66	56	49
23	73	62	55
24	81	69	61
25	89	77	68

APPENDIX VI

TABLE OF PROBABILITIES ASSOCIATED WITH VALUES AS SMALL AS OBSERVED VALUES OF x IN THE BINOMIAL TEST

Given in the body of this table are one-tailed probabilities under H_0 for the binomial test when $P = Q = \frac{1}{2}$. To save space, decimal points are omitted in the p's.

N \ x	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5	031	188	500	812	969	†										
6	016	109	344	656	891	984	†									
7	008	062	227	500	773	938	992	†								
8	004	035	145	363	637	855	965	996	†							
9	002	020	090	254	500	746	910	980	998	†						
10	001	011	055	172	377	623	828	945	989	999	†					
11		006	033	113	274	500	726	887	967	994	†	†				
12		003	019	073	194	387	613	806	927	981	997	†	†			
13		002	011	046	133	291	500	709	867	954	989	998	†	†		
14		001	006	029	090	212	395	605	788	910	971	994	999	†	†	
15			004	018	059	151	304	500	696	849	941	982	996	†	†	†
16			002	011	038	105	227	402	598	773	895	962	989	998	†	†
17			001	006	025	072	166	315	500	685	834	928	975	994	999	†
18			001	004	015	048	119	240	407	593	760	881	952	985	996	999
19				002	010	032	084	180	324	500	676	820	916	968	990	998
20				001	006	021	058	132	252	412	588	748	868	942	979	994
21				001	004	013	039	095	192	332	500	668	808	905	961	987
22					002	008	026	067	143	262	416	584	738	857	933	974
23					001	005	017	047	105	202	339	500	661	798	895	953
24					001	003	011	032	076	154	271	419	581	729	846	924
25						002	007	022	054	115	212	345	500	655	788	885